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Indianapolis

Integrating Reverse Osmosis to Reclaim Wastewater Effluent for Industrial Reuse in a Manufacturing Facility

A Directed Project Report

Submitted to the Faculty

of

Purdue School of Engineering and Technology

Indianapolis

by

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In partial fulfillment of the requirements for the

Degree of Master of Science in Technology

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Abstract:

Every day, environmental concerns are growing more and more prevalent on social media, in the news, and in the corporate business culture. People are driving more electric vehicles, looking for ways to use renewable energies, and eliminate unnecessary waste from their everyday lives. Corporations are more environmentally conscious than ever and are setting aggressive environmental responsibility targets. These initiatives create a challenge for facilities managers, who are often tasked with developing real world solutions to achieve corporate targets.

Water is now considered a scarce resource and facilities managers must find ways to reduce water usage or find ways to reuse the water that has already been purchased. Depending on the site's infrastructure and the quality of its wastewater, a reverse osmosis system may provide a feasible solution to treat and reclaim wastewater for industrial reuse.

Facilities managers who are able to implement reverse osmosis systems demonstrate their commitment to minimizing the impact of the facility on the environment and demonstrate their ability to harness a complex waste product and turn it into a commodity for the organization. Considering reverse osmosis for wastewater reuse can help facilities managers achieve corporate environmental initiatives. Properly integrating a complex equipment system such as RO is critical to equipment performance, operability, and maintainability.

Introduction

The industrial revolution combined with the rise of capitalism has resulted in a plummet of global poverty and resulted in an ever-expanding global economy. An increase in natural resource extraction to produce goods and services has been required to meet the global consumer demand. Increased concern around the extreme use of natural resources for production has led to a growing movement of corporate responsibility in recent years to encourage the collective ethical use of natural resources in business. As a result, corporations have developed initiatives, goals, and targets to reduce their consumption of natural resources, where possible. These environmental initiatives often manifest in electrical energy usage reduction, increasing the amount of renewable energy consumed vs. carbon-based energy, reducing or eliminating the disposal of waste into landfills, and decreasing the amount of water required for industrial use.

Historically, water has been regarded as a renewable resource. The water cycle produces a natural abundant supply of fresh water in many parts of the world. However, in recent years it has become evident that the amount of water the earth can supply is limited. The world is accepting that water is a scarce resource and corporations are looking for creative ways to reduce water consumption.

Reducing water consumption can be achieved in two ways: modifying processes to use less water (i.e. open loop cooling vs. closed loop cooling) or reclaiming water already used, treating it, and using it again.

Background

Cummins Jamestown Engine Plant (JEP) was constructed in 1968 and was built by Art Metal, a metal office furniture company. After the construction of the facility, Art Metal fell on hard financial times and the facility was never used for furniture production. Facing unionization, Cummins, headquartered in Columbus, IN, purchased the approximately one million square foot facility in Jamestown, NY to experiment with a new business model of worker equity and ownership in the manufacturing process. Production of components began in the mid-1970s. The plant has since grown to be one of Cummins' most critical manufacturing facilities, producing hundreds of heavy-duty diesel engines daily. The plant machines engine blocks, heads, flywheels, and camshafts, and assembles the M11, X12, and X15 engines. JEP experienced record production in 2017, shipping more than 124,000 engines to OEMs.

In 2010, the Cummins corporate Health, Safety, and Environmental (HSE) group developed environmental targets around, energy, water and waste reduction to be achieved by the end of 2020. The HSE group developed ways to normalize the metrics across the various manufacturing plants, set goals for each plant, and has tracked progress towards each goal. Given its aging mechanical infrastructure, JEP has focused most of its resources on replacing older, inefficient equipment with more modern equipment that requires less resources. For example, all H/V units were converted from steam to direct-fire natural gas, all air compressors were upgraded to include premium efficiency motors and variable speed capability, and all plant lighting was changed from fluorescent to LED. Little to no improvement has been made with regard to water usage.

Early in 2019 JEP formed a cross functional team to brainstorm ideas to decrease water intensity for the plant (Appendix B). Facilities, Plant Engineering, HSE, and Machining functions were represented at the meeting. During the brainstorming session, topics such as condensate capture, rainwater harvesting, and increasing cycles of concentration for the cooling towers were discussed. However, considering cost, schedule, readiness, and scale, it was determined that installing a reverse osmosis system to reclaim and reuse wastewater effluent was the most viable option to bring JEP into HSE environmental goal compliance.

Problem Statement

Integrate a reverse osmosis system into the JEP wastewater treatment process that will capture wastewater effluent and treat it to a quality acceptable for reuse in industrial applications.

Significance

If JEP does not achieve its water intensity reduction target (Appendix A) by the end of 2020, it will be viewed as non-responsive to corporate environmental responsibility initiatives, which calls into question 1) JEP's commitment to corporate environmental responsibility and 2) JEP's competency to engineer and execute facilities projects to achieve targets. Furthermore, with the above questions in mind, consideration for future business at JEP might be jeopardized.

Literature Review

As global society advances, an increasing amount of resources are required to produce the products and services demanded by consumers. As a result, corporations are attempting to help mitigate resource exhaustion `through corporate environmental responsibility programs, which place reduction goals on electrical and water consumption and waste generation. Many corporations pursue energy management certifications through ISO 5001 and target zero landfill certification, but water consumption reduction targets have lagged behind energy and waste goals. According to The World's Water Volume 7: The Biennial Report on Freshwater Resources, "Diversions from rivers, pumping from wells, and pollution by farms, cities, and industry all compromise the supply of water. Each of these activities has contributed, over the span of many years, to the current crisis." The report goes on to state, "Emerging corporate practice and research suggest that the environmental, political, and social realities of the 21st century mean that environmentally and socially responsible corporate water management is not only a moral responsibility for companies, but also increasingly an integral part of ensuring business viability and reducing business risk" (Gleick, et al., 2012). As a result of corporate environmental initiatives specifically focused on water usage reduction, facilities managers can be faced with the challenge of developing process solutions to achieve corporate goals.

Reverse Osmosis for Water Reuse

There are effectively two ways to reduce resource consumption: decrease the demand for the resource or develop a means to recycle the resource and extend its life. For example, replacing an open loop cooling tower system with a closed loop cooling tower system will reduce evaporation and consequently reduce the demand for water. Reclaiming wastewater and reusing it in cooling towers is a way of recycling water and effectively extending the life of the water. Similarly, capturing rainwater and treating for industrial reuse harnesses a resource that is often viewed as waste.

There are two approaches to treating reclaimed wastewater for reuse: evaporation and reverse osmosis (RO) filtration. Kamla Jevons and Martin Awe examine the economic benefits of these two technologies for further treating wastewater. They state that evaporators require a lesser initial capital investment, but operating costs of a reverse osmosis system can be more than 75% less than an evaporation system due to the high steam requirements of the evaporation process. More efficient evaporation systems are available, but to achieve comparable efficiency to RO filtration, capital costs rise to double that of RO (Jevons & Awe, 2010). They conclude that RO filtration is more economical for filtering wastewater for industrial reuse.

J.E. Cruver examines the viability of RO technology for different waste streams. Cruver says that RO is uniquely suitable for treating sanitary waste and industrial waste for reuse, given certain feed qualities. Cruver concluded in stating, “ it may be said that operating costs of reverse osmosis processing of waste streams for reuse are competitive today with those of many raw water sources” (Cruver, 1975).

An article published in the *Journal of Sustainable Water in the Built Environment* titled “Decentralized Water Reuse: Implementing and Regulating Onsite Nonpotable Water Systems” examines onsite wastewater treatment facilities designed with the specific intent for reuse. The article notes that up to 95% of the water demand in commercial buildings is nonpotable. The authors state, “A well-designed (onsite nonpotable water system) may significantly offset potable water use in a commercial and multifamily residential buildings because the majority of demand is for nonpotable uses." The article claims that research shows that meeting the water demands of the 21st century will require a combination of local and municipal water supply sources (Lackey, Sharkey, Sharvelle, Kehoe, & Chang, 2020).

Cruver discusses RO feed parameters and how certain feed parameters, specifically chemical oxygen demand (COD) and total dissolved solids (TDS), are limiting to RO performance (Cruver, 1975). RO feed produced from manufacturing wastewater effluent has the potential to have high COD and TDS. Difficult feed water fouls conventional RO membrane modules, which requires more frequent chemical cleanings leading to decreased membrane longevity and increased operational downtime. Fortunately, technology advances in 3D modeling and membrane manufacturing have allowed the development of specialized RO membranes that have mesh spacers in between layers of spiral wound membranes that allow for less pressure drop across the membrane and reduces the fouling rate, which leads to greater membrane flux and longer intervals between cleanings. Three articles, "Influence of Spacer Thickness on Permeate Flux in Spiral-Wound Seawater Reverse Osmosis Systems," "Improvements in RO Technology for Difficult Feed Waters," and "Biofouling in Spiral Wound Membrane Systems: Three-Dimensional CFD Model Based Evaluation of Experimental Data" all examine in detail the effects of various membrane spacers of different thicknesses, and the correlation between spacer thickness, pressure drop, membrane flux, and the rejection of various contaminants.

An article titled *Design Considerations for Wastewater Treatment by Reverse Osmosis* builds on Cruver's case around membrane fouling. The article states, "The primary issue limiting the use of RO technology was the issue of membrane fouling… This makes the system difficult to operate and eventually shortens the life of the RO membranes" (Bartels, Wilf, Andes, & Iong, 2005). The article discusses colloidal fouling, which can be both mineral and organic, and states that RO feed pretreated by ultrafiltration (UF) or microfiltration (MF) significantly increase chemical cleaning intervals (750 hours of operation to 3,000 hours of operation). Bartels et al. continue discussing biofouling, which is the presence of bacteria, which can foul the RO membranes. Similar to colloidal fouling, this can be controlled most effectively through the use of UF or MF pretreatment. For organic RO membrane fouling, the authors suggest the use of a coagulant prior to UF or MF, which binds the organic material together preventing it from passing through the UF or MF membrane and therefore preventing it from reaching the RO membrane. Finally, the authors discuss scaling, which "is most often due to silica, calcium carbonate, or calcium phosphate precipitation." Scaling can be mitigated by dosing an antiscalant into the feed water to prevent the membranes from fouling due to scaling (Bartels, Wilf, Andes, & Iong, 2005).

RO technology is appropriate for wastewater reclamation in pursuit of corporate environmental objectives for facilities managers. However, given the variability in feedwater and the effect of feedwater quality on membrane performance and membrane life, it seems prudent to consult with an expert during system design and integration.

Purpose

The purpose of this directed project was to develop a facilities reverse osmosis (RO) project that would reclaim wastewater effluent, treat the wastewater effluent to a quality acceptable for industrial reuse, identify the most appropriate end users of the RO product water, and develop operational controls to ensure optimal operation of the equipment.

Definitions

Deionized Water – DI Water

JEP – Jamestown Engine Plant

MBR – Membrane bioreactor

POTW – Publicly Owned Treatment Works

RFA – Request for Appropriation

RO – Reverse Osmosis

Water Intensity – Gallons used per labor hour

Assumptions

The project will assume the following conditions:

1. The corporation is willing to fund the project
2. JEP operations and maintenance staff have a developed understanding of wastewater plant operation.
3. JEP operations and maintenance staff know how to take wastewater samples and transfer to a sample courier using appropriate chain of custody forms.
4. System design engineering will be executed by a consulting engineer and will not be done internally, as Cummins does not have RO design expertise in house.

Scope/Delimitations

The scope of this project includes the design, procurement, installation of equipment, integration into existing systems, and a brief control plan for the operations staff. This project does not address detailed mechanical, electrical, controls, or network considerations, but focuses on RO process considerations with regards to wastewater reclamation and project management considerations as a facilities manager for a large-scale manufacturing plant.

Methodology

A brainstorming session was held in 2019 (Appendix B), which concluded with an agreement to pursue a project to design, purchase, and install a reverse osmosis system that will treat wastewater effluent for industrial reuse in the plant.

Given the extraordinary nuance described in the literature review, it was necessary for JEP to contract a wastewater consultant with expertise in RO technology. A study was conducted, and a comprehensive sampling plan was executed. Once the characteristics of the wastewater effluent were understood, the consultant assisted JEP in competitively bidding two equipment suppliers. To further ensure success of the project, the equipment suppliers were also responsible for integration engineering.

Once the equipment supplier has been selected, capital funds were appropriated to the project. The JEP facilities manager will submit a Request for Appropriation (RFA) to the corporation in pursuit of capital. Once capital was appropriated, the facilities manager worked with the equipment supplier to drive system and integration design during procurement of the RO equipment. The facilities manager submitted a second RFA to fund integration equipment (pumps, piping, etc.) and RO equipment integration.

The facilities manager worked closely with all stakeholders, including operators, end users, management, and the sewer district for integration. The facilities manager developed scopes of work for contractors, obtained quotes for installation, and manager the installation process such that no other processes are interrupted. The facilities manager coordinated commissioning and work with contractors, operators, and the equipment supplier during start up.

The facilities manager defined Key Performance Indicators for RO operation and develop a plan to measure the success of the project.

Results

Bid Process

JEP Plant Engineering contracted with Sustainable Water, a water/wastewater consulting firm, to complete a preliminary study to estimate 1) potential water volume recovery and 2) water quality profile of discharge to inform the local Publicly Owned Treatment Works (POTW) of the water quality they would be receiving after the project is complete (Appendix C). Estimated annual water volume savings total approximately 14M gallons/year. At first glance, cooling towers and deionized (DI) water systems were the most logical end users for the RO water, and calculations assumed these would be the end users. Loading to the POTW would remain constant, with significant volume decrease resulting in higher concentrations. This was communicated with the

POTW authorities who supported the project and indicated that the JEP sewer bill would actually be reduced by approximately $20,000 annually.

JEP and Sustainable Water developed a wastewater sampling plan to develop a profile of JEP's wastewater effluent that would be the feed for the future RO (Appendix D).

JEP approached two wastewater equipment companies it had worked with on previous projects. CrossTek Membrane Systems (CrossTek) provided JEP with a ceramic ultrafiltration used to separate water from industrial oily wastewater upstream of the sanitary treatment plant. H2O Innovation provided JEP with an MBR sanitary wastewater treatment plant in 2019, used to treat UF permeate combined with sanitary wastewater from the JEP. Both companies provide RO equipment and have experience treating MBR effluent for industrial reuse. Flow data and feed quality data was provided to both companies. The supplier was made aware they would be responsible for integration engineering, to include storage, transfer, and distribution. A Current State and Future Map are included in Appendices E and F.

Commercial proposals were received from both H2O Innovation and CrossTek. Each company proposed different RO technologies. H2O Innovation proposed a conventional RO membrane while CrossTek proposed a Spacer Tube RO (STRO) membrane, the technical characteristics and benefits of which are outlined in the Literature Review. In evaluating these two options, JEP and Sustainable Water looked at the COD and SDI of the RO feed sample analysis in Appendix D. Wastewater effluent with levels >250 mg/L COD and >4 SDI is considered "difficult" feed for conventional RO membranes, although well within the acceptable range for STRO membranes outlined in CrossTek's proposal.

From a cost standpoint, the system proposed by CrossTek is significantly more expensive, \$394K compared to \$318k cost of the H2O Innovation system, but considering the additional pump redundancy installed on the skid in the CrossTek proposal, and the more robust membrane technology, the CrossTek proposal is viable and competitive. In addition, STRO has the ability to achieve a 90%+ recovery rate, where the recovery rate for conventional RO is limited to 80-85%, likely closer to 80% given feed characteristics.

After carefully considering each proposed technology package, the decision was made to award CrossTek the contract.

In consulting with Sustainable Water and CrossTek, a preliminary total project cost estimate of \$980K was agreed upon, to be finalized after integration engineering, which would be used in the first Request for Appropriation (RFA). A two-RFA approach was pursed for the project. The first RFA would include the STRO equipment skid from CrossTek, which had a 5-month lead time, and fund integration engineering. The second RFA would fund ancillary equipment, to include RO water storage, transfer, and distribution systems, and installation of all equipment.

Cummins corporate HSE developed a *Cost of Water* calculator in attempt to capture the true cost of a gallon of water, which includes indirect costs such as pumping, backflow preventer inspection, sewer discharge fees, permits, etc. This tool was used at the direction of corporate HSE to estimate cost savings for water projects, included in Appendix G. This calculator indicates the cost of a gallon of water for JEP is $0.0212.

In good faith, CrossTek began looking at water usage data for the three assumed end users: cooling towers for facilities, cooling towers for engine test, and the DI water system, using a 3-year average rather than the 2017 single year snapshot used in the Sustainable Water study. CrossTek found, through balancing wastewater effluent, RO throughput, and end user demand, and factoring in 90% recovery rate, that the estimated annual water savings totaled 15M gallons compared to 14M gallons estimated by Sustainable Water. The 15M gallons/year figure was used for cost justification.

Cummins corporate finance provides capital project managers with a calculator that is to be used with all capital projects. The calculator determines net present value (NPV), internal rate of return (IRR), payback period in years, and annual depreciation, among other financial factors. Relevant snapshots from this calculator are included in Appendix H. The NPV for the project is $841,131, the IRR is 26%, and the payback period is 3.5 years.

Integration Design

JEP, CrossTek, and Sustainable Water set up weekly calls to review engineer progress and discuss action items for each member of the team. Integration engineering was the responsibility of CrossTek and funded in RFA 1. It was determined that three pumping systems were needed: one pumping system to pump MBR effluent to the RO skid, one system to pump RO water from the storage system, located in the

JEP wastewater treatment building, to the boiler room in the main engine plant, and one system to distribute water from the boiler room to each of the three end users. JEP Plant Engineering developed a flow diagram, attached in Appendix I. CrossTek completed detailed engineering of each pumping system, to include online dosing stations, online pH, conductivity, oxygen reduction potential (ORP), pressure, and temperature sensors. A recirculation loop is included in each system to adjust the quality of the water, both before and after the RO system, in real time.

Based on flow through the RO and the end user demand profile, CrossTek determined a total storage volume of 35,000 gallons is necessary to achieve 15M recovered gallons annually. It was determined to put a single 12,000 tank in the boiler room, near all the end users, where water would be pumped to each user as required by user demand. The production cooling towers are filled by an underground well, and by adjusting the level setpoints of the well an additional 5,000 gallons of storage is available. The remaining 18,000 gallons of storage would be achieved by installing four 4,500 gallon tanks in the JEP wastewater treatment facility and connecting the tanks at the bottom with 6” pipe, effectively allowing them to act as one 18,000 gallon tank. JEP Plant Engineering developed a layout for the tanks, included in Appendix J.

During design reviews, it became clear that the number of instruments, pump systems, valves, and dosing stations required to automate the system was significant. As such, CrossTek proposed each of the three pumping systems be built on a skid in a factory, pre-piped and wired, and shipped to JEP for installation. This would limit on site effort to providing power and ethernet to control panels and connecting suction and discharge piping. CrossTek developed P&IDs for this option and provided a commercial cost for the engineering and construction of these pump skids. With the development of P&IDs, JEP Plant Engineering was able to develop statements of work for mechanical and electrical installation, which allowed the project team to understand a total project cost of $1.2M, which is more than the initially estimated $980K. Total cost rollup is included in Appendix K. A design memo Completed by CrossTek documenting how the system was designed, including flow, temperature, storage, pump sizing, etc., is included in Appendix L.

After total costs were fully understood, the second of two RFAs could be written and submitted. A second NPV calculator was completed using total the updated total project cost of $1.2M (Appendix M). The increase in total project cost resulted in the adjustment of financials; NPV is $549,758, IRR is 18%, payback period is 4.4 years. Savings and maintenance expense did not change from RFA 1.

Installation, Commissioning, and Closeout

Equipment arrived at JEP in various stages and mechanical and electrical installation was completed as equipment arrived. A 1,500 foot 4” schedule 80 PVC transfer pipe used to transfer RO water from the wastewater treatment plant to the boiler room was installed concurrently with equipment by the mechanical contractor.

Given the significant physical distance between the boiler room, communication between the two PLCs could not be direct ethernet. JEP Plant Engineering worked with JEP network IT develop a communication plan between the two locations. The PLC in each location would be wired to a network switch, and communication would be sent via VLAN on the Cummins network. The network system uses fiberoptic between the main engine plant and the wastewater treatment building, so it was concluded lag in communication would not be an issue.

Speed and complexity of installation was significantly reduced because of the pump skid strategy developed during design. All equipment included on each of the pump skids had power, communication, and physical piping already installed when the skids arrived at JEP. Contractors simply had to provide power to a power panel included on each skid, ethernet to the controls panel, and install suction and discharge piping. This significantly reduced field labor and schedule.

After all equipment was installed, CrossTek traveled to the JEP site for commissioning. The commissioning team consisted of a CrossTek programmer, project manager, and process engineer, JEP Plant Engineering, and JEP Operations team. Commissioning lasted approximately 3 weeks and ended with 2 days of operator training by CrossTek.

Limitations

It is well known that RO technology is temperamental to feed characteristics. Feed temperature and certain contaminants in the feed will change the requirements of the RO for it to be successful. Each facility has different contaminants in its wastewater, therefore there will be unique design characteristics for each application.

This project will focus on the reclamation of wastewater for industrial reuse. The product water produced by the RO will not be potable and not intended for human consumption.

Conclusion

To date, not enough information has been gathered to determine if the project achieves the corporate water reduction initiative. Due to the COVID-19 pandemic, JEP facilities operations are staggering the schedules of team members so that if one team member was to get infected, they will not infect the entire team. This has caused an operation strain on the team, and because the RO is not a critical system, it was decided to suspend RO operation until the team can operate in full capacity. The facilities manager has developed a log sheet for the operations team to use once the system is started back up again. The log sheet includes flow data by user and quality metrics such as pH, conductivity, and ORP. These will be critical to monitor once operation resumes. JEP will work with CrossTek to determine acceptable levels of each variable.

However, the team has run the system at full flow in bursts, proving the system can treat water at a rate to achieve the target. There is still work to be done balancing the flow out of the MBR into the RO. The MBR has three independent trains that run in batches. Currently, all three trains treat together and then go into standby together. In theory, the system can be programmed to stagger trains in standby, creating a more consistent flow to the RO. This improvement is planned for 2020.

With regards to the project execution, deciding to have pump skids fabricated and assembled off site made installation go extraordinarily smoothly. Field labor is subject to many more variables than in a controlled factory setting. Error can be identified during acceptance testing in a factory. Spare parts, pipe, fittings, etc. are much more readily available in a shop that builds equipment skids regularly than in the field. Facilities managers should consider having equipment skids built off-site whenever possible, given the benefits when it comes to installation.

Between 2018 and 2019, JEP averaged total water usage of 30M gallons annually, and an average of 3.55M labor hours, for an average water intensity of 8.45 gallons per labor hour. Using projected water reductions of 15M gallons per year, JEP will purchase 15M gallons in 2020 if the RO runs full time and recovers water at the designed rate. Assuming similar labor hours of 3.55M, water intensity is projected to be 4.22 gallons per labor hour, which is well below the corporate target of 5.32.

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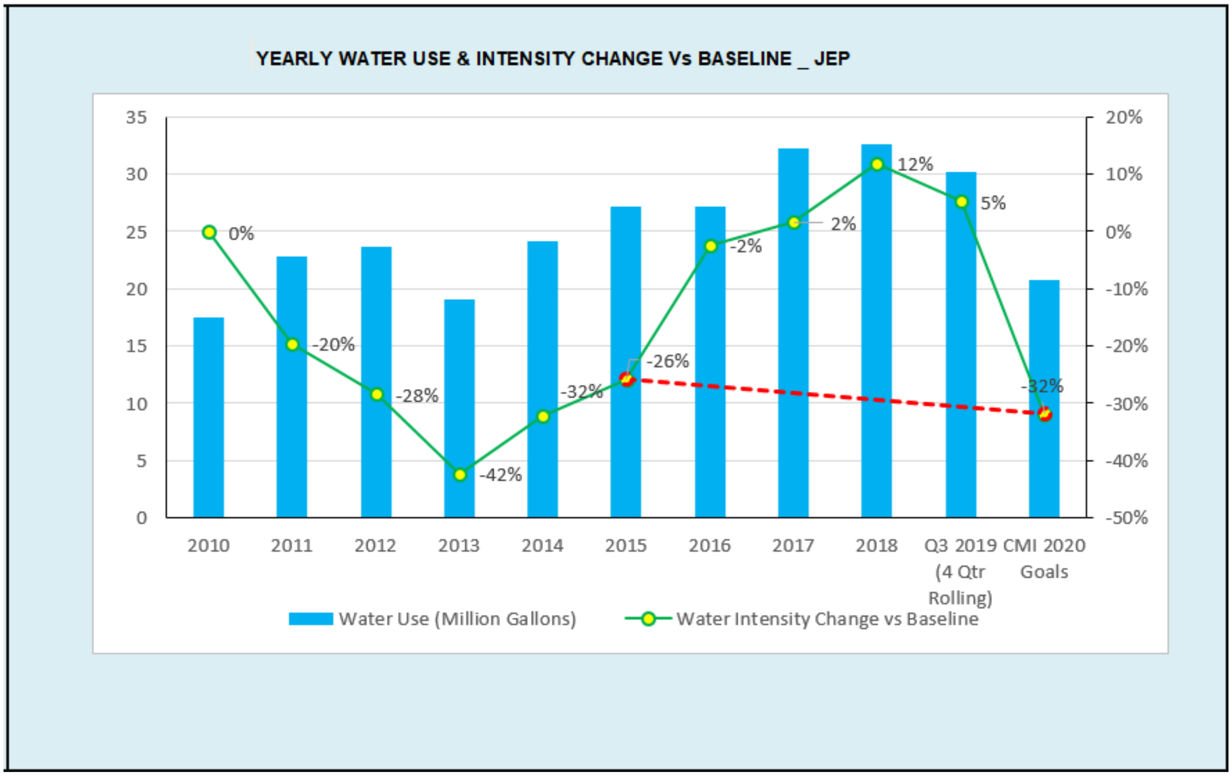
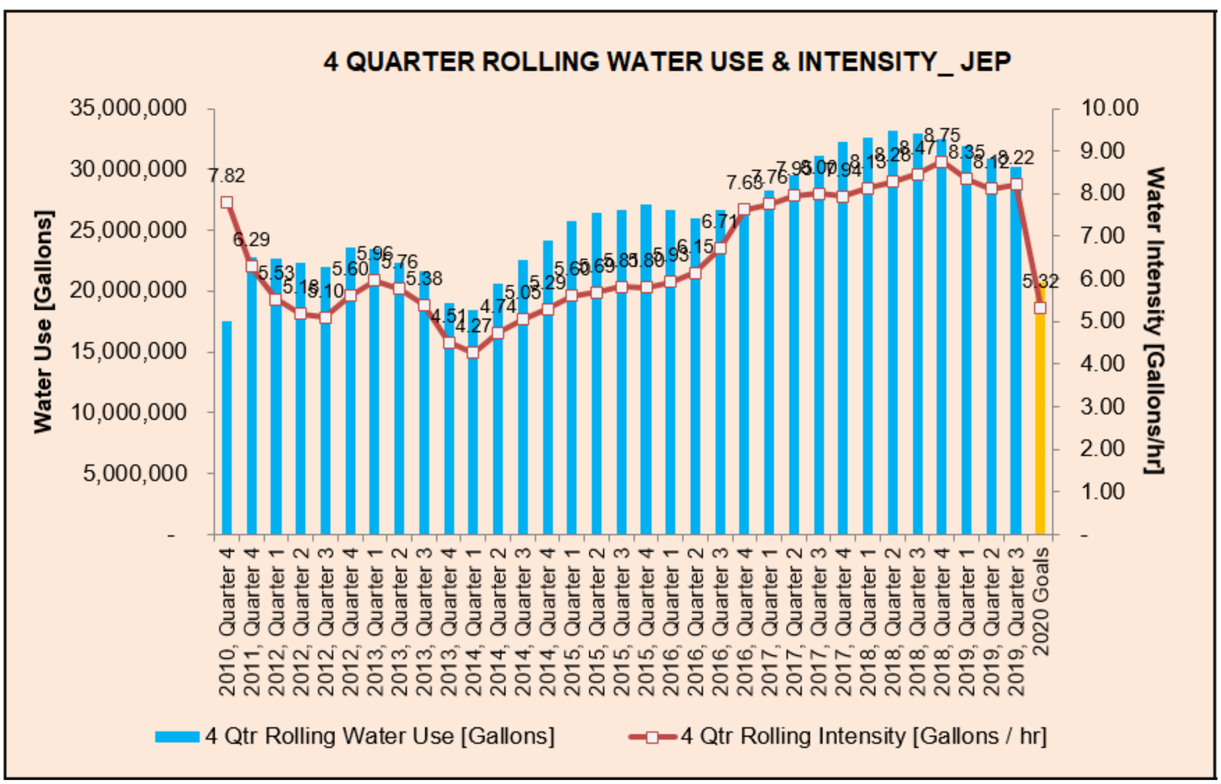
Appendix A: JEP Water Intensity Reduction Goals





Appendix B: Water Reduction Brainstorming Results

What	Target	% of Total Water
Water Balance/Data Review	Achieve +/- 10%	N/A
RO Reuse Evaluation	14 MGY	43%
Water Softener Evaluation	Increase CoC by 3x-4x	
Cooling Tower Closed Loop Evaluation	2-4 MGY	6-12%
Condensate Capture	200 GPD	0.2%
Fire System Usage Metering	Usage Metering & Repair	
Meter Calibrations (Main & Sanitary)	Usage Metering & Repair	N/A
Point of Use Sub-Metering - Process Based	Usage Metering & Repair	N/A
Barkhausen Proess Redesign Process Evaluation	2,000 GPD	2%

Appendix C: Sustainable Water Preliminary Study

Memo:

Sewer Discharge Calculations

Jamestown Engine Plant

Lakewood, NY

Sustainable Water

4200 Innslake Dr., Suite 102

Glen Allen, VA 23060

804.965.5590

www.sustainablewater.com

Memo

Preliminary calculations were performed to estimate the mass and concentration of sewer discharge from the Cummins JEP engine plant system under a maximum water reuse scenario.

A determination of waste activated sludge (WAS) for the Membrane Bioreactor treatment process was estimated from Biowin models provided by the treatment system vendor H2O Innovation dated March 2016. WAS flow was estimated at 3% or 1,410 gpd at an average influent flow of 47,000 gpd. The treatment system is designed for an average flow of 47,000 gpd and a maximum flow 80,000 gpd though it can handle daily peaking above 80,000. Values are presented in Table 1.

Table 1. Estimated Membrane Bioreactor Influent and WAS values based on Biowin modelling.

Wastewater Treatment Process

Average Influent	47,000	gpd
Average WAS	1,410	gpd

	Influent		**WAS**		
	mg/l	kg/d	mg/l	kg/d	Remaining
BOD	1,000	176	1,863	9.8	5.6%
TKN	150	26	141	0.74	2.8%
TSS	400	70	3,100	16.3	23.3%

Cummins has a corporate goal of reducing water use at their plants by at least 20%. Due to a long history of water efficiency measures across their facilities further reduction in water use is only possible with onsite water reuse initiatives. The two largest possible uses for reclaimed water at the JEP facility are Cooling Tower make-up and Deionized Water System make-up. Annual average make-up values are estimated from 2017 data compiled by the JEP facilities staff. A preliminary Water Budget is presented in Table 2. During a future engineering phase, the sizing of the reverse osmosis system will be determined and a more accurate determination of the percentage of effluent pumped through the RO system and the RO system reject rate will be made. Based on design experience with a reuse system for another Cummins engine plant it is estimated that 80% of effluent will need to be run through the RO system to meet reclaimed water targets for this project and 20% of RO flow will be discharged to sewer as RO reject.

Table 2. Estimated Reuse Project Water Budget

Average Influent	47,000	gpd
Average WAS	1,410	gpd
MBR Permeate	45,590	gpd
Average Cooling Tower Make-Up	24,000	gpd
Average DI Water Make-Up	13,000	gpd
Average Total Reuse	37,000	gpd
RO Flow Rate	36,472	gpd
Non RO Flow Rate	9,118	gpd
RO Reject	20%	
RO Reject	7,294	gpd
RO Permeate	29,178	
Reclaimed Effluent	38,296	gpd
Non Reused Water	1,296	gpd
Total Discharge to Sewer	10,000	gpd
Annual Water Savings	**13,977,894**	**gal**

Estimated mass and concentration of sewer discharge is presented in Table 3 based on the estimates provided in Table 1 and Table 2 for both water reuse and non-reuse scenarios. Reuse at the JEP facility has the potential to save almost 14 million gallons of water annually.

Table 3. Estimated Sewer Discharge Mass and Concentrations

Sewer Discharge

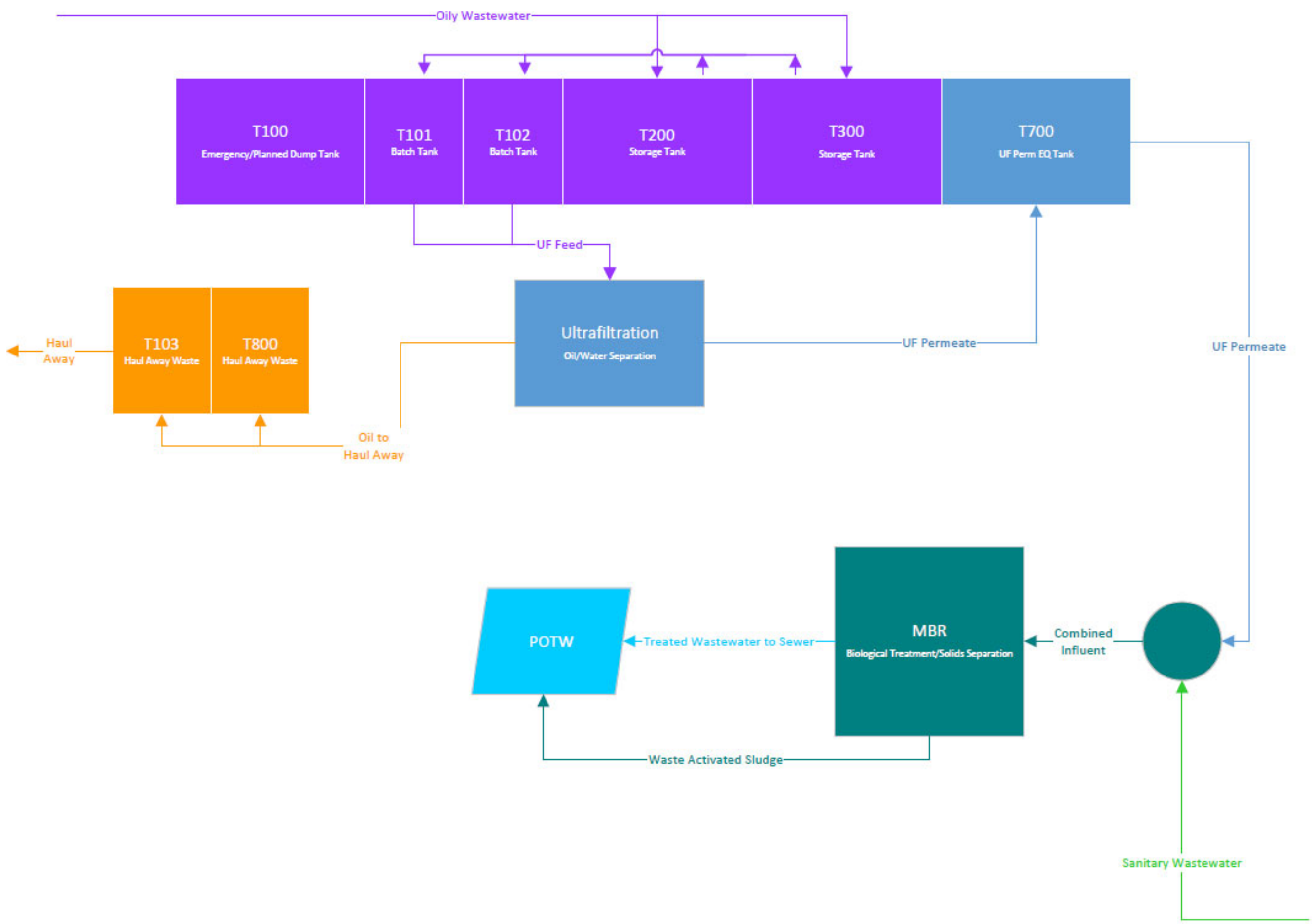
	Reuse		**No Reuse**	
	Sewer Discharge		**Sewer Discharge**	
	mg/l	kg/d	mg/l	kg/d
BOD	285	11	61	11
TKN	43	2	9	2
TSS	446	17	95	17

Appendix D: Wastewater Quality Sampling

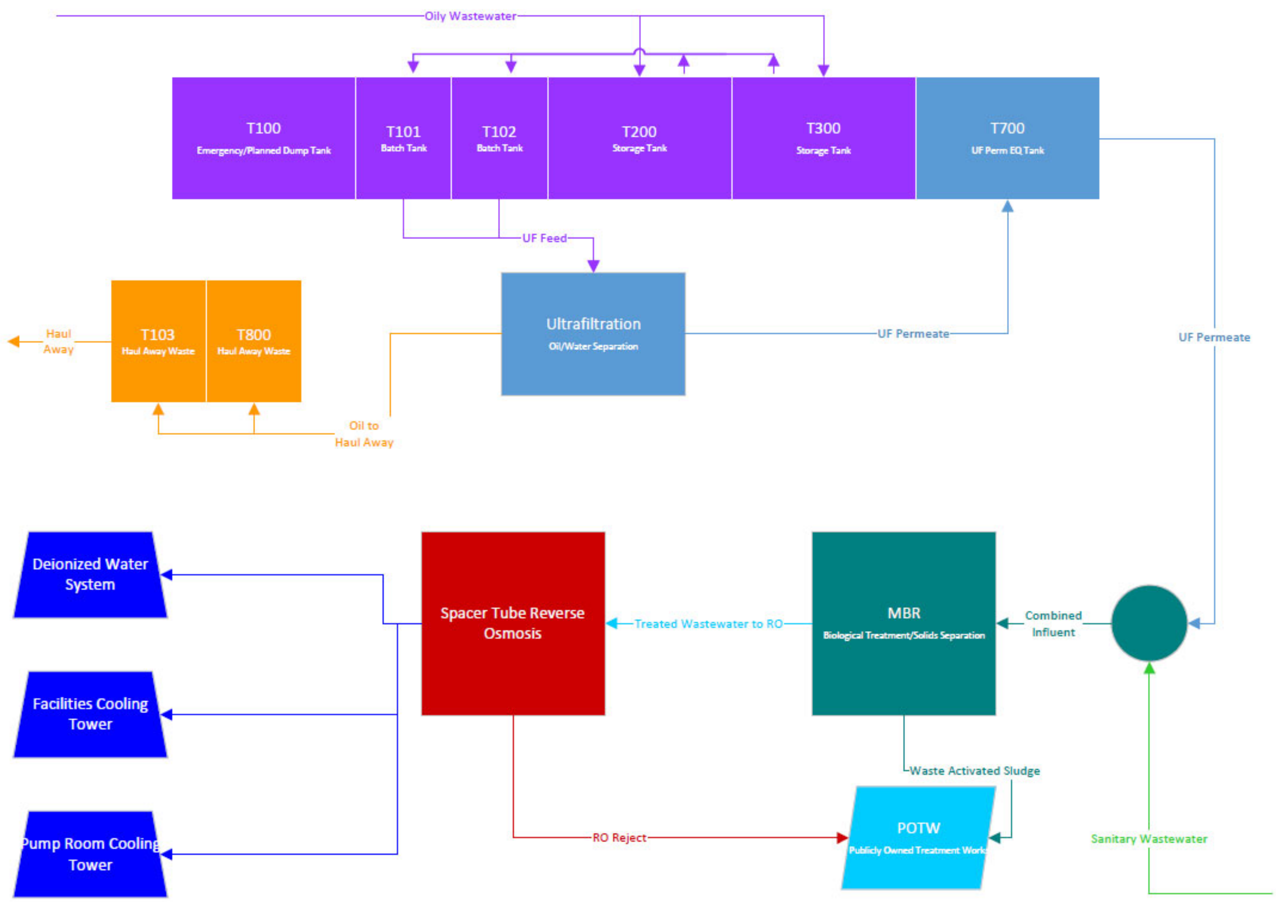
Table 1: Feed Conditions used for process design

Parameter	#1	#2	average	unit
Ortho P, Diss	8.31	8.13	8.22	mg/l
Chloride	618	613	615.5	mg/l
Fluoride	5.5	5	5.25	mg/l
Phosphorous, total	9.31	9.01	9.16	mg/l
SiO2 (dissolved)	30.8	26.4	28.6	mg/l
Sulfate	249	256	252.5	mg/l
Sulfide, Acid soluble	1.5	2.2	1.85	mg/l
Barium	524	491	507.5	ug/l
Calcium	160000	147000	153500	ug/l
Magnesium	25000	23900	24450	ug/l
Potassium	87300	94400	90850	ug/l
Sodium	449000	415000	432000	ug/l
Strontium	310	280	295	ug/l
Alkalinity, HCO3 as CaCO3	58.8	31.6	45.2	mg/l
Ammonia as Nitrogen	1.35	8.92	5.135	mg/l
pH			7.5	pHU
Silt Density Index (15minute)			4	
Silt Density Index (15minute) Maximum			5	
Chem. Oxygen Demand (COD)			260	mg/l
Chem. Oxygen Demand Maximum from Data:			1,170	mg/l

Appendix E: Wastewater Treatment Process Current State Map



Appendix F: Wastewater Treatment Process Future Map



Appendix G: JEP Cost of Water Calculator

JEP Cost of Water Calculator					
Total Incoming Water (gal/yr.)		32,200,000			
Industrial Waste Water (gal/yr.)		6,500,000			
Industrial Waste Water Permeate (sent to Sanitary) (gal/yr.)		4,500,000			
Sanitary Waste Water (not including Permeate) (gal/yr.)		8,500,000			
Total Waste Water Discharged to Sewer (Sanitary + Permeate) (gal/yr.)		13,100,000			
Incoming Water Cost ($/yr.)	$	163,000.0	$	0.0056	$/gal-used
Sewer District Fees ($/yr.)	$	67,200.0	$	0.0051	$/gal-discharged
Electric Pumping Cost at Pump House ($/yr.)	$	4,000.0	$	0.0013	$/gal-pumped
Chemical Treatment Cost (Chlorination/Pipe Treatment) ($/yr.)	$	2,000.0	$	0.0007	$/gal-treated
Storage Tank Maintenance ($/yr.)	$	25,000.0	$	0.0455	$/gal-stored
Backflow Preventer Inspections ($/yr.)	$	1,000.0	$	333.33	$/unit
Internal Distribution Pipe Maintenance - Parts ($/yr.)	$	20,000.0	$	0.0200	$/sqft.
Facilities Labor Costs associated with Water Dist. System ($/yr.)	$	40,000.0	$	0.0400	$/sqft.
Utilities Labor Costs associated with Industrial & Sanitary Maint. ($/yr.)	$	100,000.0	$	0.0076	$/gal-treated
Industrial Waste Water Treatment Maint. Parts Costs ($/yr.)	$	100,000.0	$	0.0154	$/gal-treated
Industrial Waste Water Treatment Chemical Costs ($/yr.)	$	77,000.0	$	0.0118	$/gal-treated
Sanitary Waste Water Treatment Discharge Fees ($/yr.)	$	70,000.0	$	0.0053	$/gal-discharged
Permits, Testing & Licensing ($/yr.)	$	15,000.0	$	0.0005	$/gal-used
Total Cost ($/yr.)	$	684,200	$	0.0212	$/gal-used

Notes: JEP uses both Well and City water. We have 550,000gal of onsite storage with 2 tanks. Our facility is 1,000,000 sqft. Our waste treatment plant consists of 3 Ultrafiltration units for Industrial Waste, and 4 Biological tanks for Sanitary. We have 3 Utilities Operators and 8 Facilities personnel. The water distribution system is 40yrs old. There are 3 main backflow preventers in the system. We are required to have at least one certified Water Operator on-site per NYS code. We are required to perform semiannual pretreatment testing (40 CFR Part 403) and weekly Sanitary testing (Local Law).

Appendix H: NPV Calculator Supplementing RFA 1

Section 1: Summary	
Weighted Average Cost of Capital (WACC)	9%
Effective Tax Rate (ETR)	21.5%
IRR (estimate)	15%
Net Present Value (NPV)	$841,131
Internal Rate of Return (IRR)	26%
Payback Years	3.5

Section 2: Capital Investments

		May-19	May-20	May-21	May-22	May-23	May-24	May-25	May-26	May-27	May-28	May-29
Assets	Depreciable Life	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Land	-											
Building	30											
Building Other (e.g. Roofs)	20											
Plant Machinery and Equipment	12	$ 980,000										
Office, medical and cafeteria furnishings / Outdoor Signs	10											
Office Equipment/Furniture & Automobile	8											
Software Development	5											
Tooling	4											
Leasehold Improvements* (LHI)	7											

Section 5: New Sources of Cash Inflow

		May-19	May-20	May-21	May-22	May-23	May-24	May-25	May-26	May-27	May-28	May-29
		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
New Incremental Revenue*												
Costs Avoidance												
Lower Cost of Goods Sold (COGS)*												
Warranty Savings												
City Water Savings (15M gal/year @ $0.0212/gal)			$318,000	$318,000	$318,000	$318,000	$318,000	$318,000	$318,000	$318,000	$318,000	$318,000
City Sewer Bill Reduction			$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000	$ 20,000
Total Cash Inflow		$ -	$338,000	$338,000	$338,000	$338,000	$338,000	$338,000	$338,000	$338,000	$338,000	$338,000

* - See 'Notes' below

Section 6: New Sources of Cash Outflow

		May-19	May-20	May-21	May-22	May-23	May-24	May-25	May-26	May-27	May-28	May-29
		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Erosion of Existing Sales*												
RO Module Replacement							$ 18,000					
Total Cash Outflow		$ -	$ -	$ -	$ -	$ -	$ 18,000	$ -	$ -	$ -	$ -	$ -

Appendix I: RO System Flow Diagram


CPVC
Sch 80 PVC
Ethernet or 24vdc
Power
Compressed Air
Boiler Room
Domestic Water
Facilities Cooling Towers
DI Water System
3"
Domestic Water
3"
4"
3"
Test Cooling Tower Wet Well
Pump Skid 3
PID SK-70003
12,000 gal Reuse Water
Distribution Tank
PID 73000
60A 480v 3p
&
30A 120v
Network
Switch
Wastewater Treatment Plant
90 psi
100A 480v 3p
WTP MCC
4500 gal Reuse
Water Storage Tank
PID 72000C
6"
4500 gal Reuse
Water Storage Tank
PID 72000B
6"
4500 gal Reuse
Water Storage Tank
PID 72000A
2"
STRO
60A 480v 3p
&
30A 120v
6"
4500 gal Reuse
Water Storage Tank
PID 72000D
Reuse Water Storage Tank Agitator
AG-72007
Pump Skid 2
PID SK-70002
Basement
Control Panel
Power Panel
3"
WTP
SCADA
Caustic
Dosing
Station
On Demand Water
Heater
Pump Skid 1
PID SK-70001
Basement
3"
850 Gal Raw Water
Tank
PID TK-71000
4"
60A 480v 3p
&
30A 120v

Appendix J: Storage Tank Layout

TANK & SKID LAYOUT

SCALE: ⅜"=1'

Cummins Inc.

Jamestown Engine Plant
4720 Baker Street
Lakewood, New York 14750

Revisions

Project

WTP RO
TANK AND SKID LAYOUT
BASEMENT

Plant Engineering

Drawn By BDR Date 8/26/2019
Approval CW
Approval
Approval

Scale AS NOTED
Sheet 1 of 3 Sheets

Drawing No.
WTP RO Tank Layouts S-01

CURRENT LAYOUT

SCALE: ¼"=1'

Cummins Inc.

Jamestown Engine Plant
4720 Baker Street
Lakewood, New York 14750

Revisions

Project

WTP RO TANKS
LAYOUT PROPOSALS

Plant Engineering

Drawn By	BDR	Date	8/26/2019
Approval	CW		
Approval			
Approval			
Scale	AS NOTED		
Sheet	3	of	3 Sheets

Drawing No.
WTP RO Tank Layouts S-03

Appendix K: Total Project Cost

Cummins STRO system Project: Execution Budget

Quantity	Description	Crosstek P&ID	Equipment No.	Supplier	Procured by	ExW Price	Shipment to JEP (est)	Contigency (by cummins)	Contigency (by cummins)		Phase 1 Total: STRO Skid +Integrn Engg Budget @ JEP	Phase 2: Total Integration Budget @ JEP	Notes
1.0	**Skids**												
1	STRO Membrane Skid	70005 70006	SK-76001	Crosstek	Cummins	$393,770.00	$3,000.00	0%	$0.00		$ 396,770.00		Committed
1	STRO Integration Engineering	All	All	Crosstek	Cummins	$34,290.00	$0.00	0%	$0.00		$ 34,290.00		Committed
1	STRO Integration Engineering - Electrical	All	All	Crosstek	Cummins	$50,060.00	$0.00	0%	$0.00		$ 50,060.00		Committed
1	STRO Integration Engineering - Commisioning	All	All	Crosstek	Cummins	$33,780.00	$0.00	0%	$0.00		$ 33,780.00		Committed
1	STRO Membrane Skid Modification change order	70005 70006	SK-76001	Crosstek	Cummins	$38,596.64	$0.00	0%	$0.00			**$38,596.64**	Committed
1	Raw Feed Water Pump Skid	70001	SK-71001	Crosstek	Cummins	$102,188.70	$2,000.00	0%	$0.00			**$102,188.70**	No need for contigency
1	Reuse water Pump Skid	70002	SK-72001	Crosstek	Cummins	$80,306.95	$2,000.00	0%	$0.00			**$80,306.95**	No need for contigency
1	Reuse water Distribution Pump Skid	70003	SK-73001	Crosstek	Cummins	$138,684.54	$2,000.00	0%	$0.00			**$138,684.54**	No need for contigency
2.0	**Tanks**												
All	Raw Feed tank+ Reuse Storage +Distribution	All	Variety	TBD	CrossTek	$18,520.00	$9,500.00	10%	$2,802.00			**$20,372.00**	Contingency for tank modifications
3.0	**Valves**												
All	Control Valves & Manual valves	All	Variety	TBD	CrossTek	$16,643.01	$1,000.00	0%	$0.00			**$16,643.01**	No need for contigency
4.0	**Pumps**												
All	Raw feed pump+Storage Transfer pump+Dosing pumps	All	Variety	TBD	CrossTek	$35,519.50	$2,000.00	0%	$0.00			**$35,519.50**	No need for contigency
5.0	**Agitators**												
All	Raw water + Re-use Water Storage	All	Variety	TBD	CrossTek	$6,111.60	$2,000.00	20%	$1,622.32			**$7,333.92**	
6.0	**CIP Water Controls**												
	Hot water Relay (Nema 4)	70004	R74001	Cummins	Cummins	$1,000.00	$50.00	0%	$0.00			**$1,000.00**	Cummins to Provide Estimate
	Temperature controller	70004	TC2	Cummins	Cummins	$1,000.00	$50.00	0%	$0.00			**$1,000.00**	Cummins to Provide Estimate
Sub Total Equipment Price/Budget						***$950,470.93***	***$23,600.00***		***$4,424.32***		***$514,900.00***	***$441,645.25***	Removed shipping from total, paid out of different account
7.0	**Installation/Construction**												
	Installation Costs (labor)	All		Cummins	Cummins	$90,181.00	$0.00	20%	$18,036.20			**$108,217.20**	Cummins to Provide Estimate
	Installation Costs (Material)	All		Cummins	Cummins	$44,764.00	$0.00	20%	$8,952.80			**$53,716.80**	Cummins to Provide Estimate
	Misc	All		Cummins	Cummins	$2,000.00	$0.00	20%	$400.00			**$2,400.00**	Cummins to Provide Estimate
SubTotal Site Installation Price/Budget						***$136,945.00***			***$27,389.00***			***$164,334.00***	
Total Budget by Phase											***$570,000.00***	***$605,979.25***	
Overall Total Project Budget incl contingency													***$1,175,979.25***

Appendix L: RO Design Memo

July 15, 2019

1 Considerations of design flow rate for reuse RO system and end user transfer pump

1.1 Goals

1. reuse > 90% of the MBR permeate (this excludes RO reject losses of 10%)

1.2 Design considerations – flow rate

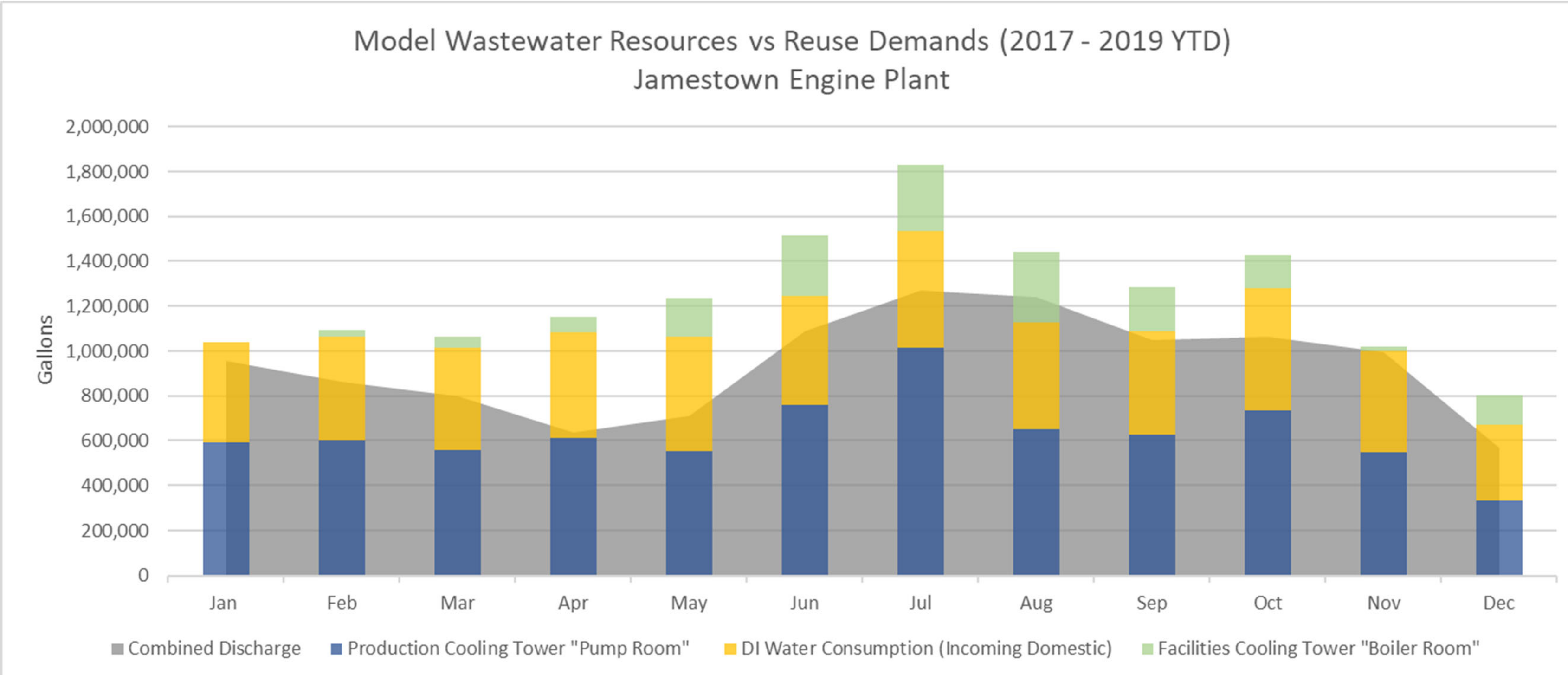
1. The nominal design issued for the reuse system was 31.66gpm MBR permeate / raw water to reuse system. This was based on 2017 and 2018 flow information, but is expected to change over the next few years as less wastewater is produced by production, but more water capture from other sources, such as rainwater from the facility roof, is achieved. The net effect is likely to be an overall increase in reuse water flow rate. The reuse system is being designed with flexibility in mind and is able to treat 50gpm in future as needed.
2. The original design for the RO skid was to treat 80% (25gpm) of the MBR permeate, bypass the additional 6.3gpm/20%, and then blend the RO permeate with the 20% bypass: the blended stream is shown in Case 1 with Case 2 showing the 80% RO permeate portion of Case 1. This design used 2 of the 4 available RO membrane rows. However, during execution, it was decided to instead treat 100% (nominally 31gpm / Case 6) of the wastewater through the RO system to improve reuse water quality. This required 3 of the 4 RO skid membrane rows to be used.
3. Based on the MBR process flow diagram revision 3, the MBR permeate forward flow rate is expected to have a maximum flow rate of 28gpm per train. MBR design is 3 x 50%, so design is 2 trains operating and 1 train in standby/backup, hence peak production of 56gpm MBR permeate. MBR nominal design is 22gpm for 2 x 50% trains operating, which relates well with the projected site future demand of 10MM gallons per year / 27,400 GPD / 19 GPM. The 3-row RO system can handle up to 38gpm (Case 7) production rate, which is between nominal and peak MBR production and double that average projected WW flow rate, hence the RO appears to provide sufficient operation flexibility to not cause flow back up in the raw WW EQ tanks (60,000 gallons MBR feed plus UF feed EQ) without adding a RO feed / MBR permeate EQ tank.
4. From design reviews, the MBR permeate flow rate is expected to have an estimated operating low flow of 20,000 gpd / 13.9gpm in 2020 and was designed for 5.6gpm minimum flow (per train) based on the MBR process flow diagram Rev.03. For the RO system. RO minimum flow rate, set by feed and booster pumps, is 9gpm (actual procured pumps), which is lower than the MBR nominal design but above the MBR minimum flow rate. At minimum RO feed rate, modelled in Case 5 as all-MBR permeate feed, the RO permeate was quality was worse than Case 1 (20% bypass case) and clearly not attractive. Below 9gpm feed flow rate, the RO system would shut down, as it was decided in the RO kick-off meeting (7/10/2019) to not add alternative water sources to the RO (such as domestic water) but rather to run the MBR and RO in batch mode (must run at least a “few” hours each day) at flows that “work” for the process (RO minimum and meet daily average). The permeate quality becomes a key issue of study, in the next section of this document, as it pertains to low flow conditions

of the wastewater reuse system. However, as mentioned, to accommodate flow rates below 9gpm instantaneous RO feed rate, the MBR and RO system will be operated in ON/OFF batch mode (to match average daily flow rate required)

Table 1: RO permeate quality at different flux values at 68oF to 77oF

	1	2	4	5	6	7
Species	80/20 25gpm	25gpm 2-rows	25gpm 3-rows	9gpm 3-rows	31gpm 3-rows	38gpm 3-rows
NH_4^+	1.90	1.00	1.58	3.00	1.44	0.98
K^+	27.22	9.56	16.27	37.31	14.60	9.40
Na^+	131.6	45.42	76.90	175.8	69.24	44.90
Mg^{+2}	6.25	1.20	2.08	5.25	1.87	1.20
Ca^{+2}	40.78	7.68	13.38	34.23	12.00	7.64
Sr^{+2}	0.07	0.01	0.02	0.06	0.02	0.01
Ba^{+2}	0.13	0.02	0.04	0.11	0.04	0.02
CO_3^{-2}	0.00	0.00	0.00	0.02	0.00	0.00
HCO_3^-	13.18	6.00	9.96	21.82	9.04	5.99
NO_3^-	0.00	0.00	0.00	0.00	0.00	0.00
Cl^-	265.4	86.45	146.7	338.6	132.0	85.42
F^-	1.63	0.63	1.04	2.27	0.94	0.62
SO_4^{-2}	61.97	9.06	15.96	42.37	14.31	9.06
SiO_2	7.59	1.75	3.06	7.89	2.72	1.71
Boron	0.00	0.00	0.00	0.00	0.00	0.00
CO_2	6.25	4.30	4.11	3.23	4.02	4.23
TDS^a	557.7	168.8	287.0	668.7	258.2	167.0
pH	6.4	6.3	6.5	6.9	6.5	6.3

5. By matching the RO system and the MBR system feed, the feed side of the wastewater reuse plant needs no additional EQ. The focus of the hydraulic design now becomes the demand side of the system. There are three end users of the water:2 CTs and a deionization (DI) system. The 2018 annual estimates show that the DI system averages about 12.3gpm and the CTs about 16.9gpm, for a total of 29.2gpm total average demand, which was the basis of the nominal design of the WW reuse system, and even after switching to 100% RO treatment (Case 6), the reuse system still is still within 3% of the demand (reuse water production flow being less than demand). However, the monthly figures showed that some months are closer than others and that annual averages can be misleading. In order to maximize utilization of reuse water (primary goal of this project), a more detailed snapshot is required: daily volume use of the end-users was considered for EQ design. Daily total use less the minimum and maximum daily RO permeate production rate, was used to determine the maximum daily end-user and minimum production freeboard volume respectively. The minimum CCE production rate was assumed to be 10,000 gallons per day based on prior experience, and per earlier design considerations, the maximum WW treatment rate was 60,640 gallons/day (38gpm RO production limited). The EQ tank was then sized to capture 95% of the wastewater produced by flow balancing, and it was determined to be 35,000 gallons with 42% freeboard (production balance). A decision was made to place a 5,000 gallons day tank near the end users in the boiler room, and to utilize approximately 5,000 gallons of storage in the cooling tower tank (production or test cooling tower). This meant the third reuse water storage tank to be built needs at least 25,000gallons working volume.



6. End user instantaneous flow rate. During the design review 7/10/19 it was agreed that level control will be used to dampen peak flow to the two cooling towers, but this was not simple for the DI system. These three systems would all share a common feed pump.

   a. The DI system was observed to flow approximately 12.5gpm during production (tank top up) and city water had a static head of 58 psig and 45psig during flow. When adding a 10psig line loss from the pump to the DI skid we expect 55psig pressure for the DI from the pump. The DI allotment to the reuse transfer pumps would be 70gpm/55psi.
   b. Data from the facilities cooling tower (FCT) show a peak flow rate of 63.3gpm using 15-minute data set (April 21, 2018 19h29). This would be a safe average to use as this tower is currently operated in on/off mode and will be switched to level control in future. The FCT tanks is on the roof top, approximately 60ft up (26psid) and through some piping where flow will be combined with the circulation flow to the towers. The frictional losses for this 60ft of pipe at maximum velocity of 15fps would likely be < 10

psid pressure drop add another 10psig for elbows/ports, and 15 psig for the LCV, for a total head of 35 psid frictional losses. The FCT allotment to the reuse water transfer pump is 70gpm / 65 psid.

c. Data for the production or test CTs (TCTs) shows a typical 70gpm net fill rate, but a -40gpm typical net dropping/loss/evaporation rate. This would require a 70-(-40)=110gpm feed supply rate to match the present design, but for future level control we need to be above the dropping/evaporation/loss rate. To allow a low case of 2 x cycles of concentration, we propose 2 x evaporation/loss rate = 2 x 40gpm = 80gpm. The TCT make up tank is at grade level and approximately 100ft away from the proposed reuse tank. The line loss at maximum 15fps velocity would be < 10psid. Additional elbows and other losses are expected to be < 10 psid, and 15 psig for the LCV, for a total of 35 psid line loss. The TCT allotment to the reuse water transfer pump is 80gpm / 35 psid.

d. Total reuse transfer pump flow rate: 70+70+80 = 220gpm. Pressure is that of the highest end user, 55psig DI system. This pump will be 3 x 150gpm, so as to allow one pump to feed the CTs continuously and a second pump to kick on when the DI system is being used intermittently. These pumps are on VFDs and be placed in the boiler room adjacent to the reuse water day tank.

1.3 Design considerations – reuse water quality

1. Since RO permeate varies with flux and temperature (assuming constant feed quality), a model that combined flow range and quality was developed to compare chloride ions in the RO permeate to the maximum target of ~ 480mg/l in the cooling tower blow down. With a target of 4X cycles of concentration, the RO permeate chloride target value was < 120mg/l.
2. An energy balance showing heat added to the RO for different production rate (at 90% recovery) showed that either cooling or membrane isolation using feed side valves would be required to reduce heat build-up in the system. Even so, heat build-up was significant (> 5oF temperature increase) below 20gpm feed flow to the RO (table below).

Feed flow	9	12.6	13	20	25.33	28	37.9	gpm
dT oF	10.32476	7.793596	7.290033	5.135989	4.265783	4.190771	3.363359	oF
cooling	13.4693	14.23414	13.73711	14.88938	15.66234	17.00884	18.47715	kW

3. The effect of temperature on permeate quality, at temperature corrected flux, is shown in Table 2: Case 7 through 10 below. Based on cases 7 through 10, flux would need to be maximized for the membranes to manage permeate quality. It is clear that achieving 4X COC (120 mg/l Cl- in RO permeate) will be challenging on the warmer days with RO permeate temperature >~81oF, even at design / maximum flux. This would require maximum feed temperature be 77oF assuming running > 25 gpm flow (2 rows full flux) – feed temp TBC. Since maximum temperature is expected to be > 77oF, it may be best to run the CTs at 3.5 COC and return more CTBD to the MBR/RO as these can handle the additional water based on the hydraulic balance reported earlier in this document. The simplest control of RO systems with stable feed quality for higher temperatures is by maintaining feed pressure at full flux at 77oF once the feed temperature is above 77oF. But due to feed composition variations, this cannot be used reliably in this project and actual TCF would need to be applied in the control system. Permeate conductivity will also be monitored online in the system. It should be noted that for the case of 2 rows of RO

operating (minimum to manage temperature) the flow rates for Case 7 through 10 would be 2/3rds that of Table 2 at the similar permeate qualities reported in Table 2. The design uses the RO system with either 2 or 3 rows operating and operating at full TCF up to 48gpm at 91oF. For the minimum average flow rate of 10,000GPD, the RO/MBR will be operated 3.5hrs/day as a minimum.

Table 2: RO permeate quality versus temperature at design flux (3 rows of RO membranes)

	7	8	9	10

Species	38gpm 68oF	38gpm 77oF	43gpm 85oF	48gpm 91oF
NH_4^+	0.98	1.25	1.38	1.45
K^+	9.40	12.41	14.07	15.03
Na^+	44.85	59.26	67.54	72.60
Mg^{+2}	1.20	1.60	1.86	2.03
Ca^{+2}	7.64	10.25	11.87	12.91
Sr^{+2}	0.01	0.02	0.02	0.02
Ba^{+2}	0.02	0.03	0.04	0.04
CO_3^{-2}	0.00	0.00	0.00	0.00
HCO_3^-	5.96	7.85	8.99	9.73
NO_3^-	0.00	0.00	0.00	0.00
Cl^-	85.35	112.8	128.6	138.1
F^-	0.62	0.82	0.93	1.00
SO_4^{-2}	9.06	12.25	14.33	15.72
SiO_2	1.71	2.28	2.59	2.77
Boron	0.00	0.00	0.00	0.00
CO_2	4.19	4.12	3.91	3.79
TDS[a]	166.8	220.9	252.2	271.5
pH	6.3	6.4	6.5	6.5

Appendix M: NPV Calculator Supplementing RFA 2

Section 1: Summary

Weighted Average Cost of Capital (WACC)	9%
Effective Tax Rate (ETR)	21.5%
IRR (estimate)	15%
Net Present Value (NPV)	**$549,758**
Internal Rate of Return (IRR)	**18%**
Payback Years	**4.4**

Section 2: Capital Investments

		Aug-19	Aug-20	Aug-21	Sep-22	Sep-23	Sep-24	Sep-25	Sep-26	Sep-27	Sep-28	Sep-29
Assets	Depreciable Life	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Land	-											
Building	30											
Building Other (e.g. Roofs)	20											
Plant Machinery and Equipment	12	$ 1,200,000										
Office, medical and cafeteria furnishings / Outdoor Signs etc	10											
Office Equipment/Furniture & Automobile	8											
Software Development	5											
Tooling	4											
Leasehold Improvements* (LHI)	7											
LHI-Lease Term	*7*											
LHI-Asset Life	*10*											
Total Capital Investments		$ 1,200,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -